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Engineering Design File

OU 3-13 Group 1, Tank Farm Interim Action, Evaporation Pond Sizing Design

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Idaho National Engineering & Environmental Laboratory
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1. Project File No. 020978 2. Project/Task OU 3-13 Group 1 Tank Farm Interim Action

3. Subtask Evaporation Pond

4. Title: OU 3-13 Group 1, Tank Farm Interim Action, Evaporation Pond Sizing Design

5. Summary: The Waste Area Group 3, Operable Unit 3-13 Record of Decision (ROD) for the Group I—Tank Farm Interim Action requires installation of engineering controls to reduce infiltration of water into the contaminated Tank Farm soils. This Interim Action includes upgrading the existing storm water runoff collection system in the Tank Farm including a 150-ft drainage control zone around the Tank Farm and constructing a lined evaporation pond where storm water runoff water from the INTEC facility will be collected. The ROD requires the storm water collection system to accommodate a 25-year 24-hour storm event. In addition, the evaporation pond must be designed to evaporate the runoff from the annual precipitation at the Facility. This EDF provides the design calculations and assumptions for the design of the lined evaporation pond.

Using the design calculations and assumptions provided on the following pages, an evaporation pond having a bottom surface area of 75,000 ft^2, a maximum water depth of 15 feet with 3:1 side slopes, and a storage volume of 1.26M ft^3 would be sufficient for this Interim Action. This size of pond was designed to contain the 25-year snowmelt event (2.8 inches of precipitation equal to 8.3 feet of depth), which exceeds the 25-year rainfall event (1.73 inches (NOAA, 1996)). (See Attachment 1.) Typically, this pond will be filled to a depth of 2 to 6 feet and evaporate 220,000 ft^3/year, exceeding expected average runoff (125,000 ft^3/year). An analysis of 50 years of weather data indicates that this pond will have to be drained approximately every 8–10 years to provide capacity for high return period spring snowmelt events.

A small ditch leading away from the outflow of the pond will be used during drainage events to transport the flow into the desert where *it* will infiltrate into the ground. Rip-rap will be placed at the outlet for approximately 27 feet. The rip-rap is sized to accommodate a flow of 34.6 cfs (16,000 gpm). Rip-rap sizing calculations are provided in Attachment 2.

6. Distribution (complete package):

Distribution (summary package only):

7. Review (R) and Approval (A) Signatures: (Minimum reviews and approvals are listed. Additional reviews/approvals may be added as necessary.)

	R/A	Printed Name	Signature	Date
Author	R	Jestin Hurst	Jestin Hurst	9/19/00
Independent Verification	R	Kurt Fritz	Kurt Fritz	9/19/00
Requestor	A	Michelle Kaptein	Michelle Kaptein	9/19/00.

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ACRONYMS

AMC	antecedent moisture condition
CFA	Central Facilities Area
CN	Curve Number
INTEC	Idaho Nuclear Technology and Engineering Center
ROD	Record of Decision
SCS	Soil Conservation Service

OU 3-13 Group 1, Tank Farm Interim Action, Evaporation Pond Sizing Design

1. DESIGN CRITERIA

The evaporation pond was designed from water budgets, constraints on depth of water in the pond and the number of times the pond would need to be drained to accommodate possible long return percolation snowmelt runoff events. The water budget, not including the effects of transpiration:

$$\text{Evaporation Pond Storage} = \text{runoff} + \text{direct precipitation} - \text{evaporation}$$

was prepared from weather data collected between 1950 and 1999.

Runoff was determined with the Soil Conservation Service (SCS) method for small watersheds (SCS 1986). Evaporation rates were computed using the pan evaporation method (Ponce 1989). Design parameters include:

- Temperature
- Precipitation
- Sublimation
- Runoff
- Evaporation.

A description of each of the parameters and how they were incorporated into the design is described below.

1.1 Temperature

Average monthly temperatures for all months between 1950 and 1999 were derived from minimum and maximum daily temperatures that have been recorded at the Central Facilities Area (CFA) since 1950.

1.2 Precipitation

Daily precipitation data has been collected since 1950 at the CFA; however, a distinction between rainfall and snowfall was needed: if the average monthly temperature was less than or equal to 32°F, all precipitation within that month was regarded as snow, and if the average monthly temperature was greater than 32°F, all precipitation within that month was considered rainfall. Figure 1 (attached) shows the daily rainfall precipitation from 1950 to 1999.

Precipitation as snow was assumed to accumulate during months having an average temperature less than or equal to 32°F. Accumulated snowfall was assumed to melt and runoff as soon as the average monthly temperature exceeded 32°F. The method for calculating snowmelt runoff is discussed in the runoff section below. Figure 2 (attached) shows the computed daily snowfall amounts (inches of water equivalent).

1.3 Sublimation

The snowpack, if present, was assumed to sublimate at a rate of 0.5 mm/day (0.02 in/day) (Schmidt **1998).**

1.4 Runoff

Runoff was calculated using the SCS Runoff Curve Number (CN) method (SCS **1989).** The SCS runoff equation is:

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:

Q = runoff (inches) (occurs only when $P > I_a$)

P = Precipitation (inches)

I_a = initial abstraction (inches) = 0.2 **S** (mostly evaporation from surfaces)

S = Potential maximum retention after runoff begins (inches of watershed storage)

$$= S = \frac{1000}{CN} - 10$$

CN = SCS curve number

The CN depends on land surface characteristics, season, and antecedent moisture condition (AMC). CN's for a variety of land uses, seasons and average AMC's (AMC II) have been tabulated (SCS **1986). A** single season (dormant) was chosen for the Idaho Nuclear Technology and Engineering Center (INTEC) facility because it is in a desert. In addition, CN values reflect three AMC's that are defined by the total rainfall received during the preceding five days (Ponce **1989).** When conditions are drier or wetter than average (AMC **I** and *AMC* **III**, respectively), tabulated CN values are adjusted using the equations found in Table 1.

To use the SCS method, the INTEC Facility was divided into two watersheds with different CN's: **1)** the Tank Farm and all impermeable surfaces around the Tank Farm that drain through impermeable ditches and into the evaporation pond and, 2) the rest of the INTEC facility. This second watershed has both impermeable and permeable areas that drain through permeable and impermeable ditches. The SCS method requires watersheds to be divided into different subareas when significantly different conditions affecting runoff or timing are present in the watershed. Because timing (i.e., time of concentration) is not an issue for this design (generally related to sizing conveyance systems) it was not factored into the watershed determination. The topography and surface conditions are similar throughout the entire watershed except for the tank farm area. Therefore, only two watershed subareas were necessary for this design.

Table 1. Curve Number Determination.

AMC	Total 5-Day Antecedent Rainfall for Dormant Conditions	CN Equations
I	< 1.3 cm (0.51 in)	$CN_I = \frac{CN_{II}}{2.3 - 0.013 \times CN_{II}}$
II	1.3 – 2.8 cm (0.51–1.10 in)	CN_{II} = From SCS Tech –55 Tables
III	> 2.8 cm (1.10 in)	$CN_{III} = \frac{CN_{II}}{0.43 + 0.0057 \times CN_{II}}$

The first watershed (Tank Farm Area) encompasses the Tank Farm, a 150-ft perimeter zone around the Tank Farm, and approximately 50% of the surface area for the buildings adjacent to the 150-ft zone as shown in Figure 3 (attached). This area is approximately 634,000 ft^2 and is almost entirely impervious because of the surface sealing activities to be conducted as part of the OU 3-13 Tank Farm Interim Action. An AMC II CN of 98 is typically used for impervious areas (SCS 1986). AMC I and III CNs for this area, based on the equations in Table 1, are provided in Table 2 and in the attached Curve Number and Runoff Calculations Worksheet.

The rest of the INTEC facility encompasses approximately 5,805,000 ft^2. This watershed includes approximately 1,576,000 ft^2 of impervious area (i.e., buildings, paved roads, structures and sidewalks), and 4,229,000 ft^2 of pervious areas consisting of gravel, dirt and some grass. There is an existing storm water collection system in place that drains the entire INTEC facility. Although there are areas that do not drain well, no effort was performed to physically survey and evaluate the effectiveness of the existing collection system. All data used to calculate areas and curve numbers were obtained from AutoCAD drawings of the facility, the 25-year 24-hour storm analysis of the Idaho Chemical Processing Plant report by Burgess (1991), and the SCS Tech-55 manual (1986). The CN for the pervious area was based on natural desert landscaping for western desert urban areas with a Pancheri Soil (Hydrologic Soil Group B; Burgess 1991) described in SCS (1986). Because runoff flow paths in this latter area are poorly defined and include both types of surfaces, a single composite CN of 82.7 was used (82.7 is the surface area weighted average of 98 and 77; Ponce 1989). AMC I and III CN's for this area based on the equations in Table 1 are provided in Table 2 and in the attached Curve Number and Runoff Calculations Worksheet.

During snowmelt runoff, AMC II CNs of 98 and 82.7 were assumed for the Tank Farm Area watershed and the remaining INTEC facility watersheds, respectively.

Rainfall runoff was calculated on a daily basis using the historical record. Snowmelt runoff was assumed to occur when temperatures remained above freezing (defined as a month with an average temperature greater than freezing). Snowmelt precipitation used for runoff calculations was the cumulative sum of daily snowfall precipitation minus sublimation for all days in months with an average temperature less than or equal to 32°F. After snowmelt and rainfall runoff had been calculated for both watersheds, the runoff was multiplied by the respective area of each watershed to obtain a daily runoff volume (Figure 4—attached).

Assumptions about snowmelt runoff led to either a single runoff event or to no runoff in a given year. Snowmelt runoff amounts ranged from 0 to almost 4 inches (Figure 5—attached), whereas the largest rainfall precipitation event was approximately 1.7 inches (Figure 1—attached). Therefore, the evaporation pond design was controlled by snowmelt runoff rather than rainfall runoff.

Table 2. INTEC Curve Numbers.

AMC	Tank Farm Area	Rest of INTEC Facility
I	95.52	67.52
II	98	82.7
III	99.13	91.75

1.5 Evaporation

Evaporation pond water budgets utilized estimates of daily evaporation rates:

pond evaporation = K • (INTEC **pan evaporation)**

where K is a pan coefficient. A small pond pan coefficient of 0.7 was used for this calculation (Linsley 1972).

Daily pan evaporation measurements for the growing season (approximately April to October) were taken at the Aberdeen Experiment Station in southeastern Idaho; INTEC pan evaporation rates are computed from Aberdeen pan evaporation according to NOAA, 1989:

INTEC **pond evaporation** = 0.915• **Aberdeen Pan Evaporation**

When the average monthly temperature was below freezing, the evaporation pond was assumed to be frozen (evaporation = 0). The following method was used to fill in missing values for months having an average temperature above freezing. The actual and estimated monthly pan evaporation rates are provided in Table 3.

Estimates of daily pan evaporation rates during months with partial daily data. The average of available measurements for that month was used for all missing days.

Estimates of daily pan evaporation rates during months with no data. Evaporation during months having no observations was assumed to be in proportion to the percentages found in Molnau et al (1992) (bottom of Table 3). For example, if available pan evaporation measurements for May to October total 50.00 inches, the annual total is estimated to be 63.30 inches (50.00/0.79) distributed as 0.63 inches for January (1%), 1.27 inches for February (2%), 2.54 inches for March (4%), etc.

The daily pond evaporation rates (ft/day) used for this design are provided in Figure 6 (attached).

2. POND SURFACE AREA AND VOLUME

The evaporation pond was designed to contain the 25-year spring snowmelt runoff event, to be filled on average to a depth of **6** feet, and to be drained on average not more than once every eight years. Pond bottom surface area was determined from pond geometry (square footprint with 3:1 side slopes), volume of runoff produced by the 25-year return period snowmelt event, and water budget analysis using the 50 years of historical data described above. ***An*** iterative approach was used in which pond depth and number of drainage events over time were determined for a variety of pond surface area values.

Table 3. Estimated and actual monthly evaporation.

ESTIMATED MONTHS (Months with no actual data)

MONTHS WITH AVERAGE TEMPERATURE LESS THAN OR EQUAL TO 32 F

	Estimated and Actual Pan Evaporation Rates (1/100 in)											
Year	January	February	March	April	May	June	July	August	September	October	November	December
1950			0.0	297.7	725.8	620.0	771.0	626.0	362.0	255.2	170.1	0.0
1951	0.0	0.0	0.0	301.7	517.3	720.0	778.0	554.0	577.5	258.6	0.0	0.0
1952	0.0	0.0	0.0	401.0	687.4	628.3	853.9	885.0	907.3	563.8	0.0	0.0
1953	0.0	0.0	227.6	398.2	512 8	830 0	1099 0	942 0	734 5	376 0	227.6	0.0
1954	0.0	0.0	0.0	425.0	851 5	8180	10400	1006.0	7260	3550	242.9	0.0
1955	0.0	0.0	0.0	404.7	7957	8920	9867	9580	5880	346.9	0.0	0.0
1956	0.0	0.0	0.0	412.1	7290	10120	10190	8650	671 0	354.5	0.0	0.0
1957	0.0	0.0	211.3	369.7	484.6	842 1	9640	9460	6250	311 1	0.0	0.0
1958	0.0	0.0	0.0	430.9	8003	9189	988.0	10299	671 8	4547	0.0	0.0
1959	0.0	0.0	247.6	433.4	7624	9144	1099.9	11005	5936	420.0	0.0	0.0
1960	0.0	0.0	0.0	454.6	853.0	10620	1091 0	994.0	7080	422.0	0.0	0.0
1961	0.0	0.0	230.5	403.3	8174	9660	10800	8250	5172	3463	0.0	0.0
1962	0.0	0.0	0.0	418.8	717.9	897.4	1136.7	933 3	6640	377.0	239.3	0.0
1963	0.0	102.0	204.0	357.0	701.8	607 0	1074 0	791.0	4520	4030	0.0	0.0
1964	0.0	0.0	0.0	416.3	7782	7389	1031 0	10240	6760	4505	0.0	0.0
1965	0.0	0.0	0.0	402.5	711 9	8762	9730	8329	6744	474.0	230.0	0.0
1966	0.0	0.0	274.2	479.9	1023.0	10030	12120	10890	6150	473.6	274.2	0.0
1967	0.0	0.0	241.6	422.8	811 3	7303	10730	1065.0	677.0	4150	0.0	0.0
1968	0.0	0.0	229.6	401.8	7492	9340	11220	7370	5880	4040	0.0	0.0
1969	0.0	0.0	0.0	478.8	10282	8280	11440	11410	8280	434.0	0.0	0.0
1970	0.0	0.0	0.0	425.7	761.6	8720	1025.4	10400	6530	451 9	0.0	0.0
1971	0.0	0.0	0.0	440.7	755.5	976 1	1196.3	943 0	730.0	373 1	0.0	0.0
1972	0.0	0.0	257.1	449.9	858.8	871 0	11200	936.2	702.9	5890	0.0	0.0
1973	0.0	0.0	0.0	445.4	933.6	930.0	971 0	10290	5220	640.7	0.0	0.0
1974	0.0	0.0	282.5	727.5	822.0	11070	11120	9580	7990	549 1	282.5	0.0
1975	0.0	0.0	0.0	460.7	813.0	1033.0	10860	9830	7130	4753	0.0	0.0
1976	0.0	0.0	0.0	499.1	846.0	9330	10980	8750	611.0	421.6	0.0	0.0
1977	0.0	0.0	0.0	8880	6000	11310	1054.0	9380	655.0	395.0	0.0	0.0
1978	0.0	0.0	240.6	421.0	748.3	9670	11070	969.0	5989	360.8	0.0	0.0
1979	0.0	0.0	0.0	471.3	915.0	10450	11200	9000	7760	562.9	0.0	0.0
1980	0.0	0.0	259.4	780.0	572.0	824 0	1107.0	975 0	6580	661 3	0.0	0.0
1981	0.0	0.0	238.7	532.5	655.0	1021.0	1124.0	907 9	5740	318.5	238.7	0.0
1982	0.0	0.0	241.0	771.0	798.8	824.0	949 0	956 7	5780	303 1	0.0	0.0
1983	0.0	0.0	225.4	459.0	740.0	768.6	918 2	770.0	7324	457.8	225.4	0.0
1984	0.0	0.0	0.0	432.0	8420	786.2	9806	801 9	7050	460.6	0.0	0.0
1985	0.0	0.0	0.0	432.0	809.0	10350	9150	981 0	583.4	551 8	0.0	0.0
1986	0.0	0.0	220.7	5194	794.5	8320	8530	9197	4956	331.1	220.7	0.0
1987	0.0	0.0	233.6	408.7	669.0	869.0	924 0	10750	7254	350.3	233.6	0.0
1988	0.0	0.0	269.3	471.2	848.2	984.0	12630	1137 7	681 0	403.9	0.0	0.0
1989	0.0	0.0	0.0	421.5	697.5	988.0	1038.0	941.0	731 0	361.3	0.0	0.0
1990	0.0	0.0	255.8	447.6	817.9	961 0	11470	10261	7160	383.7	0.0	0.0
1991	0.0	0.0	237.8	416.1	713.3	891.6	1111.0	983.0	640.3	356.7	0.0	0.0
1992	0.0	141.0	282.0	493.5	971.0	997.0	1211.2	1192.0	775.0	423.0	0.0	0.0
1993	0.0	0.0	0.0	408.5	811.0	853.0	1041.0	804.0	751.4	350.2	0.0	0.0
1994	0.0	0.0	282.8	495.0	843.0	1126.0	1262.0	1031.0	900.0	424.3	0.0	0.0
1995	0.0	0.0	238.2	416.9	714.6	806.8	1015.0	1049.0	762.0	357.3	238.2	0.0
1996	0.0	0.0	249.6	436.7	577.4	1060.0	1188.0	1054.0	675.0	374.3	249.6	0.0
1997	0.0	0.0	242.2	423.9	958.2	911.0	886.0	971.0	694.0	363.3	0.0	0.0
1998	0.0	0.0	217.6	380.8	710.6	647.0	1001.3	1014.0	598.0	326.4	0.0	0.0
1999	0.0	0.0	231.9	405.9	518.0	885.0	1177.0	914.0	738.9	347.9	231.9	0.0
	Percent of Annual Evaporation for Freewater Surfaces for Each Month Based on Molnau, 1992											
	0.01	**0.02**	**0.04**	**0.07**	**0.12**	**0.15**	**0.19**	**0.16**	**0.11**	**0.06**	**0.04**	**0.03**

A 25-year hydrologic event has by definition a 1/25 chance of occurring in a given year (Probability = 1/return period; 0.04 = 1/25 years). The amount of snowmelt corresponding to this probability can be estimated from the empirical (sample based) cumulative density function (CDF):

$$\textbf{\textit{sample}}\ CDF \approx \frac{i}{n + 1}$$

where n is the sample size (50 annual values) and i is the rank of a given year's runoff. The sample CDF for snowmelt events is shown in Figure 7. The value of the sample CDF for the 25 year return period event corresponds approximately to the second largest runoff event, for which the probability ≈ 2/51 ≈ 0.04. The event itself is 2.8 inches, in contrast to the 25-year 24-hour rainfall event which is 1.73 inches (NOAA 1996). **A** runoff event of 2.8 inches represents approximately 750,000 ft^3 as shown in the attached Curve Number and Runoff Calculations Worksheet.

In addition to the volume of the 25-year snowmelt runoff event, it was assumed that the evaporation pond must have the capacity to accommodate this volume prior to the spring snowmelt. It was also assumed that the pond could be drained in the fall as necessary to accommodate this volume. We assumed that a number of drainage events corresponding to the design life of the pond, or once every 8 years, would be acceptable. This is achieved with a pond having a total volume of 1.26 M ft^3. By adding an additional 510,000 ft^3 of volume to the pond with a bottom surface area of 75,000 ft^2 and 3:1 side slopes, the proposed pond would have a capacity of 1.26 M ft^3 with approximately 2 feet of additional freeboard before reaching the top of the ditches in the INTEC facility.

To calculate a cumulative daily mass balance of the water in the pond from 1950 to 1999, the existing volume of storm water in the pond was added to the daily runoff volume minus the daily evaporation. However, if the pond did not have sufficient volume (750,000 ft^3) to accommodate the 25-year snowmelt event, it was drained. From 1950 to 1999, the pond would have been drained six times: February 1961, January 1963, February 1966, March 1970, February 1987 and February 1996. Figures 8 and 9 (attached) illustrate the approximate depth and cumulative volume of water, respectively, that would have been in the pond for the 1950 to 1999 time period.

3. ASSUMPTIONS

1. The watershed areas for collection of runoff storm water for the evaporation pond design include only those areas inside the inner INTEC security fence as described previously.

2. The SCS CN for impermeable surfaces = 98 (SCS 1986)

3. The SCS CN for the pervious area was based on natural desert landscaping for western desert urban areas with a Pancheri Soil = 77 (Burgess 1991) (SCS 1986).

4. The CNs used to calculate the snowmelt runoff were assumed to be AMC II CNs of 98 and 82.7 for the Tank Farm Area and the rest of the INTEC Facility, respectively.

5. Snowfall precipitation was assumed to accumulate during all months with an average temperature less than 32°F.

6. The daily sublimation rate for accumulated snow was 0.5 mm/day (0.02 in/day) (Schmidt 1998).

7. Snowmelt runoff was assumed to occur on the last day of the month when the following month had an average temperature greater than 32°F.

8. Snowmelt runoff was calculated using the SCS method by assuming that all accumulated snow would melt and runoff in one day (i.e., one event).

9. Evaporation would not occur if the temperature was less than or equal to 32°F.

10. The evaporation rate at CFA is the same as INTEC.

11. The pan evaporation rates for days within months having some actual data were assumed to be equal the average of the existing data for that month.

12. The pan evaporation rate for months with no data and an average temperature greater than 32°F were assumed to have an average pan evaporation rate equal to the percentage of the total annual rate as described in Molnau et al, 1992.

13. All precipitation occumng during months with an average temperature less than or equal to 32°F was assumed to be snow. If the monthly average temperature was greater than 32°F the precipitation was assumed to be rain.

14. There is no difference between the climate at CFA and INTEC.

15. If the pond did not have the capacity to accommodate the 25-year snowmelt event of 750,000 ft^3 prior to the annual snowmelt event, it would be drained.

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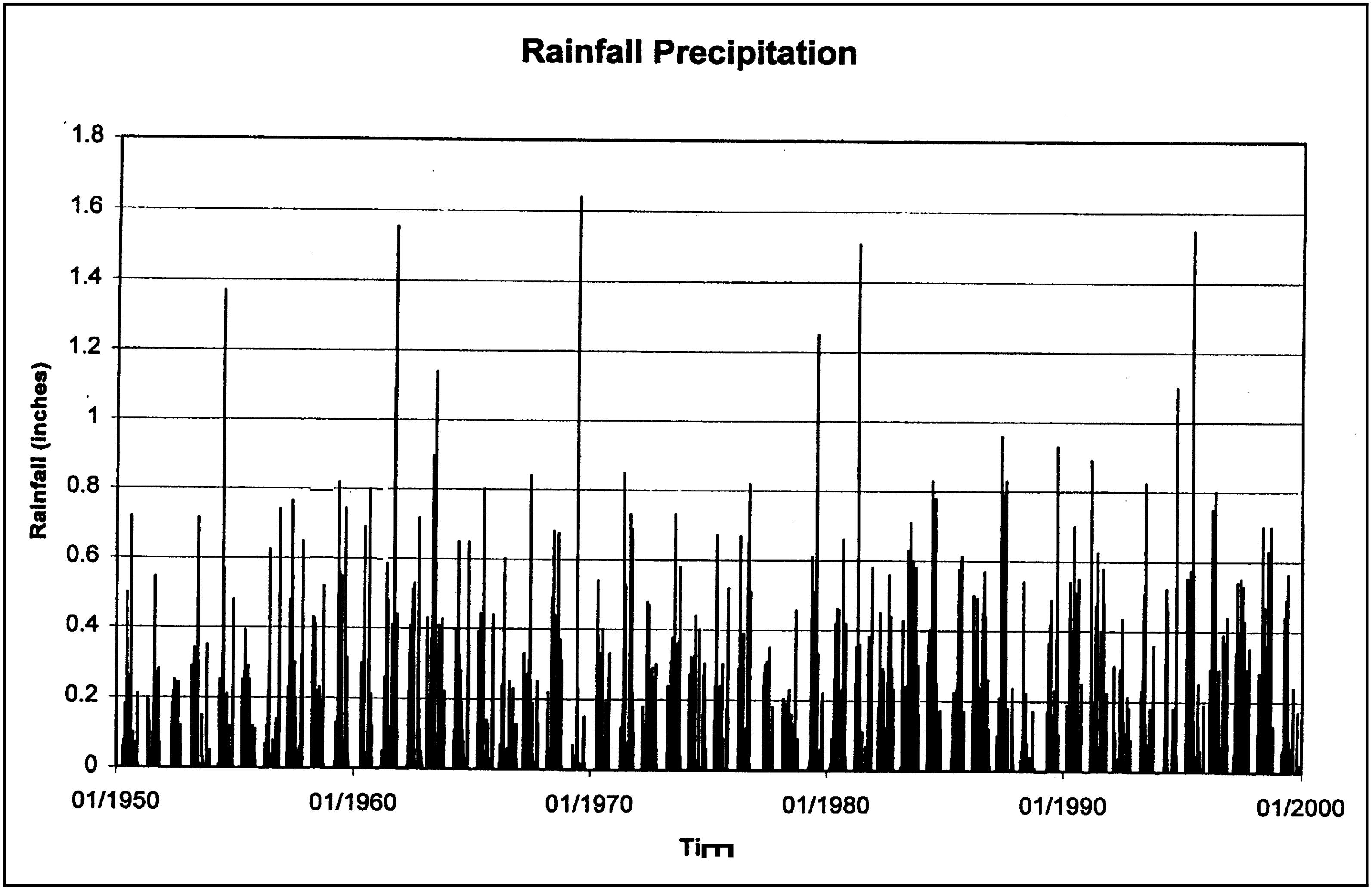

Figure 1. Rainfall Precipitation at CFA 1950–1999

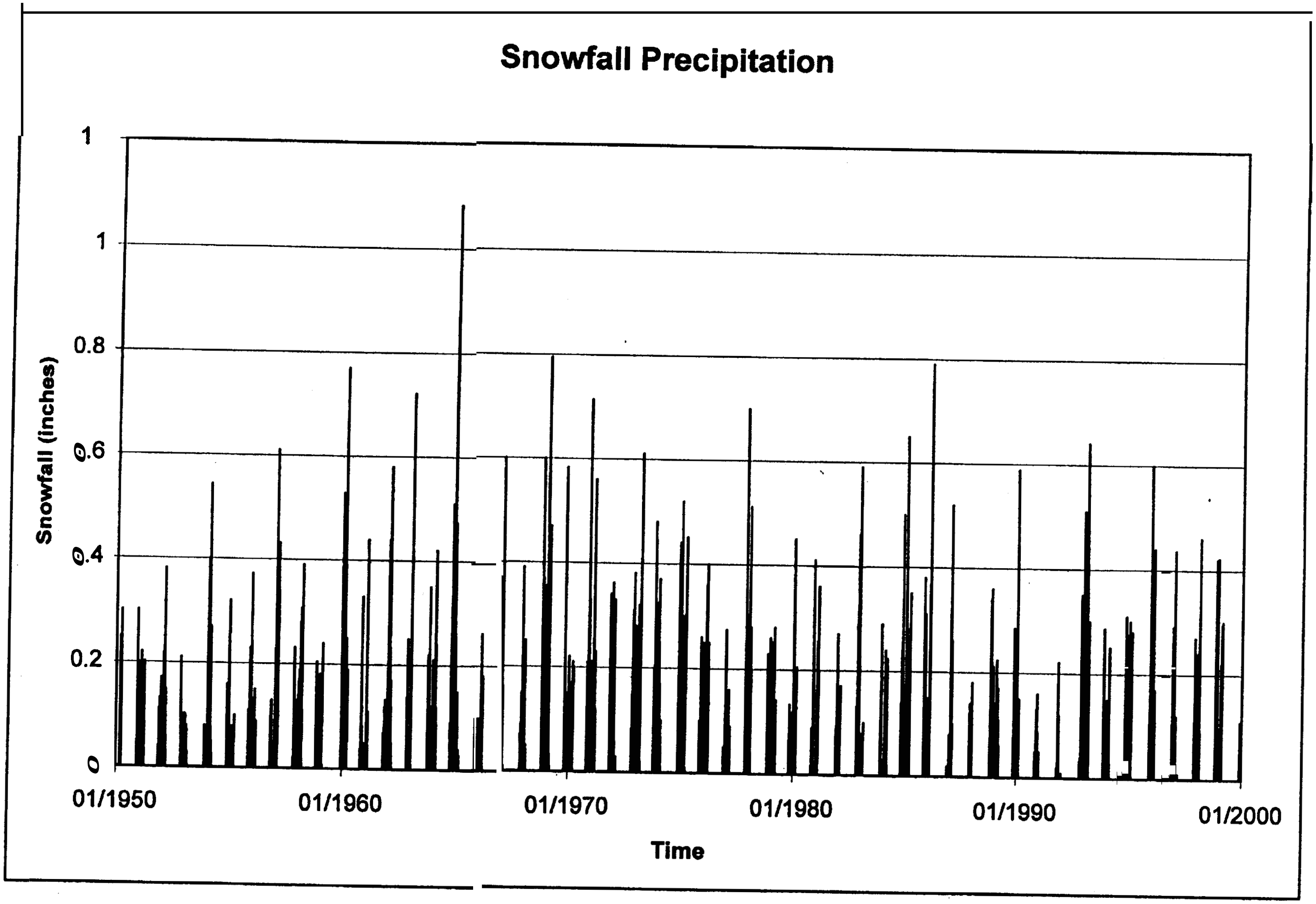

Figure 2. Snowfall Precipitation at CFA 1950–1999.

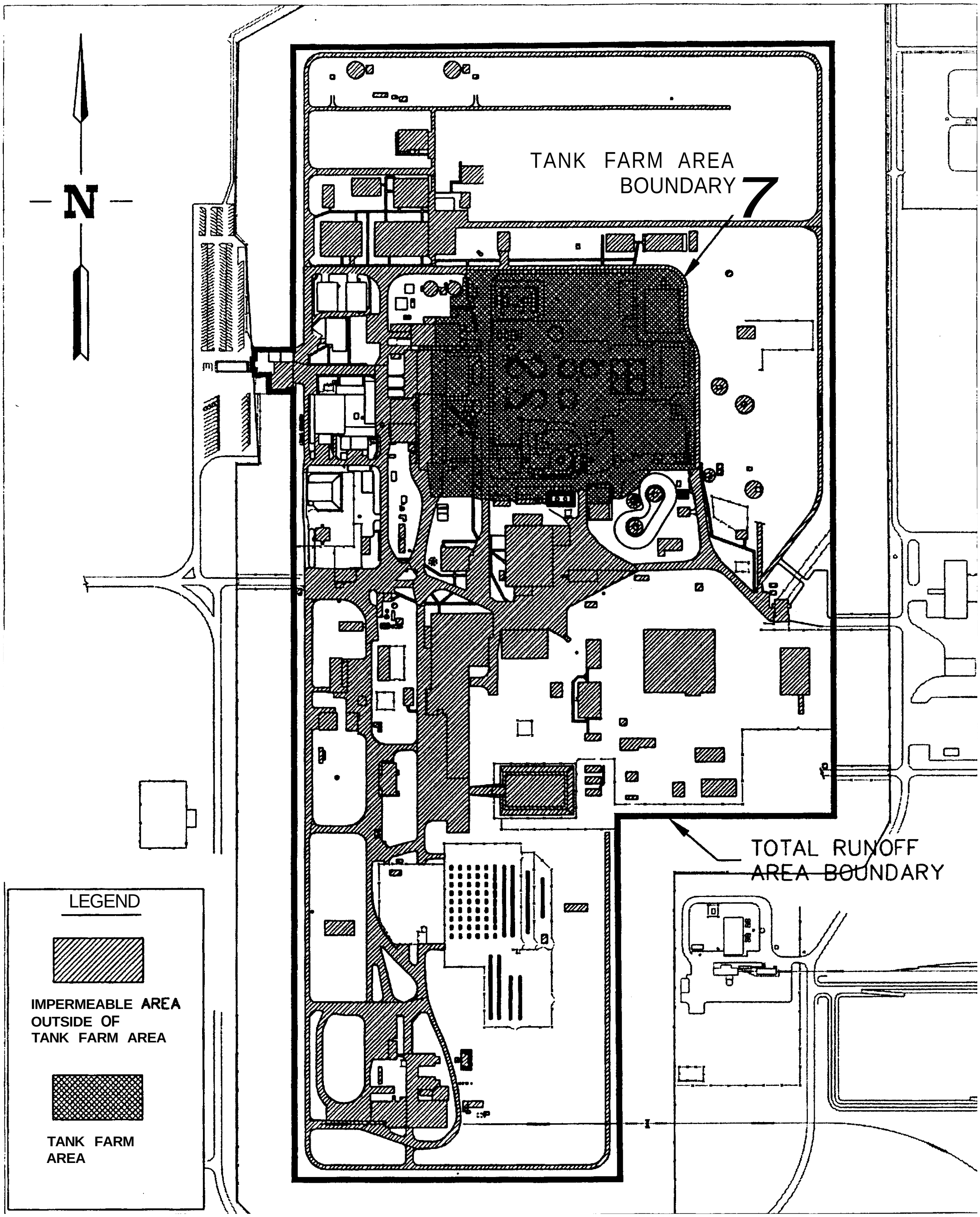

Figure 3. INTEC Runoff Watersheds.

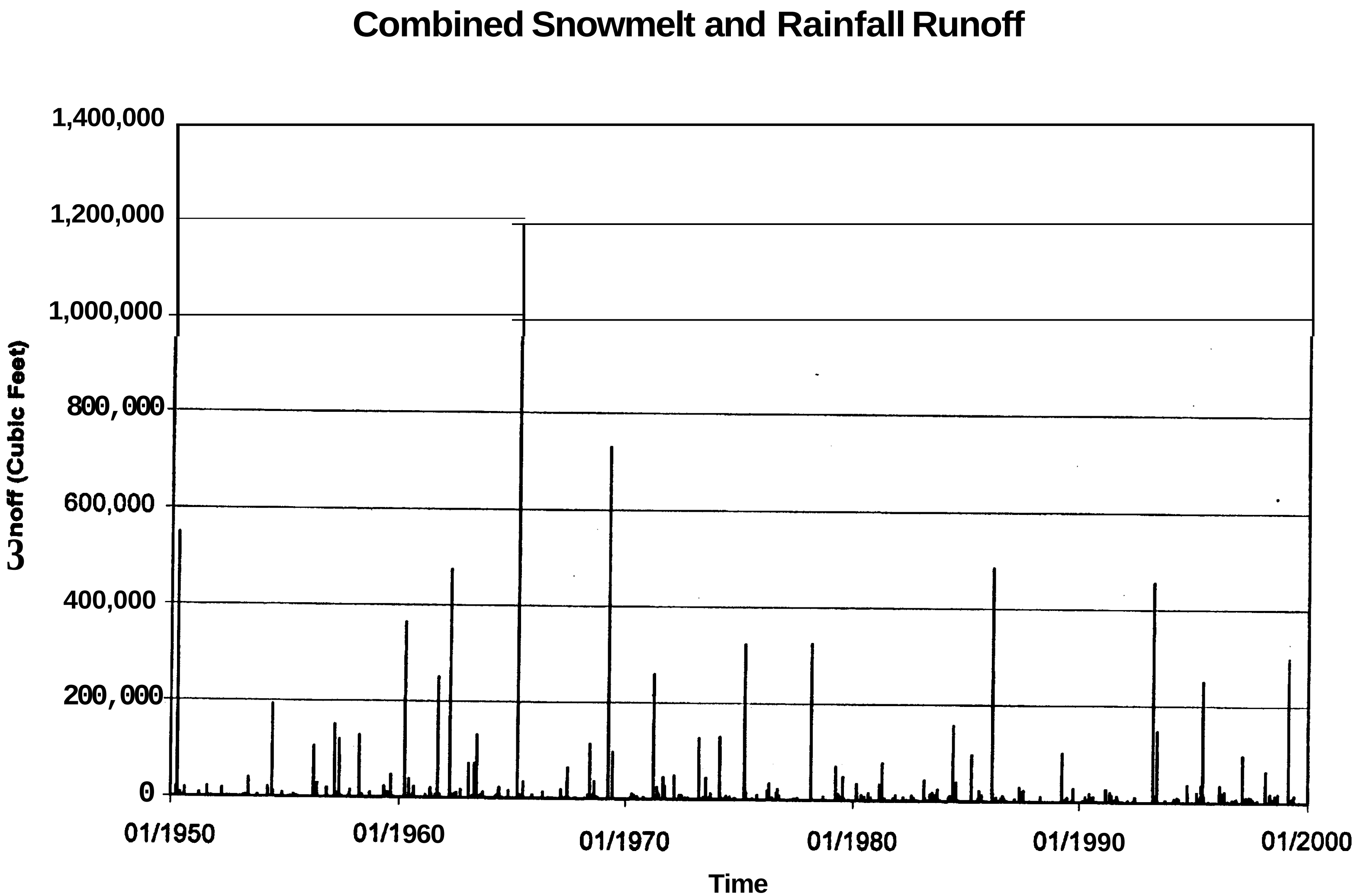

Figure 4. Snowmelt and Precipitation Runoff Volumes 1950–1999.

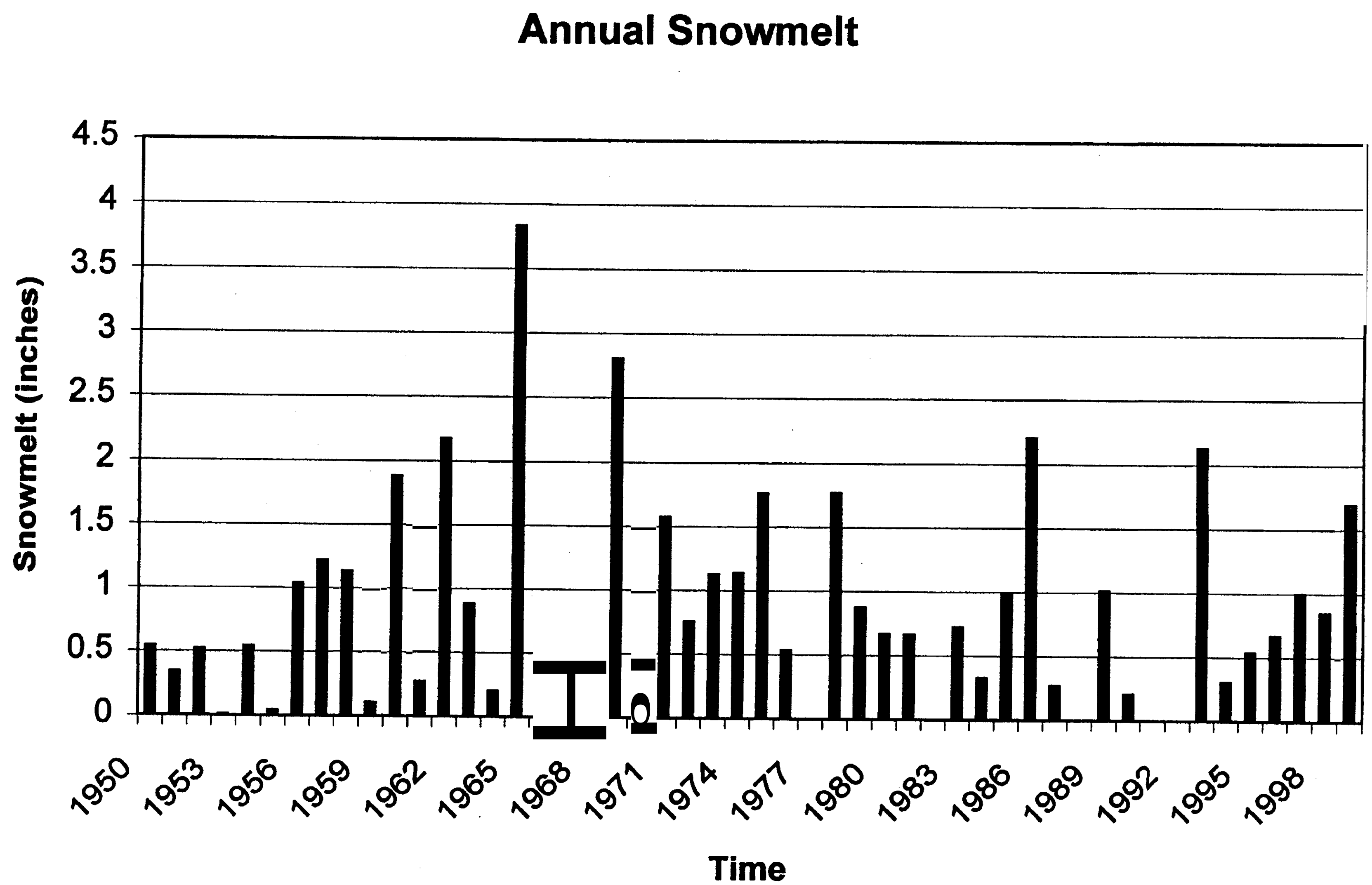

Figure 5. Annual Snowmelt 1950–1999.

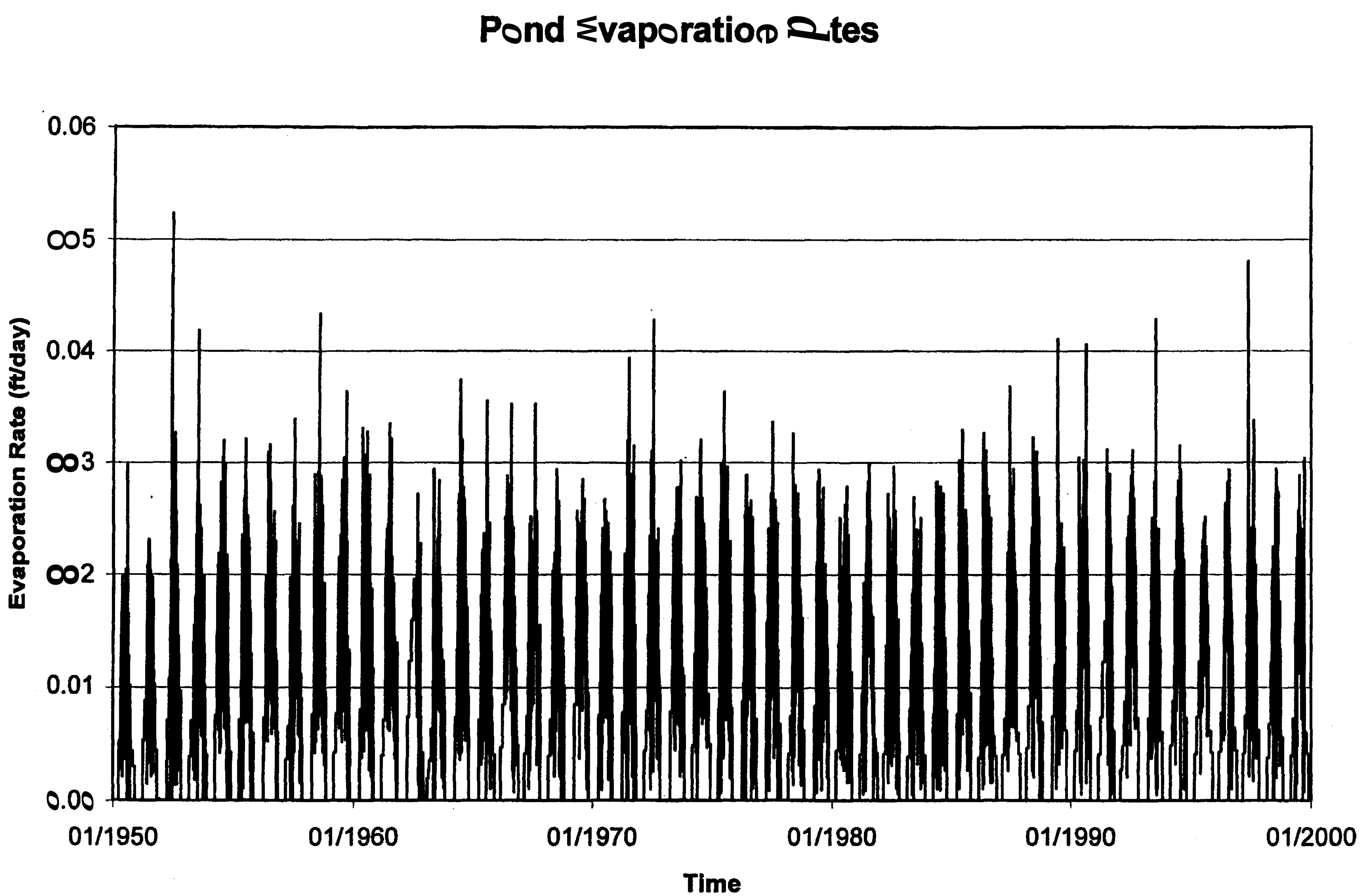

Figure 6. Pond Evaporation Rates 1950–1999.

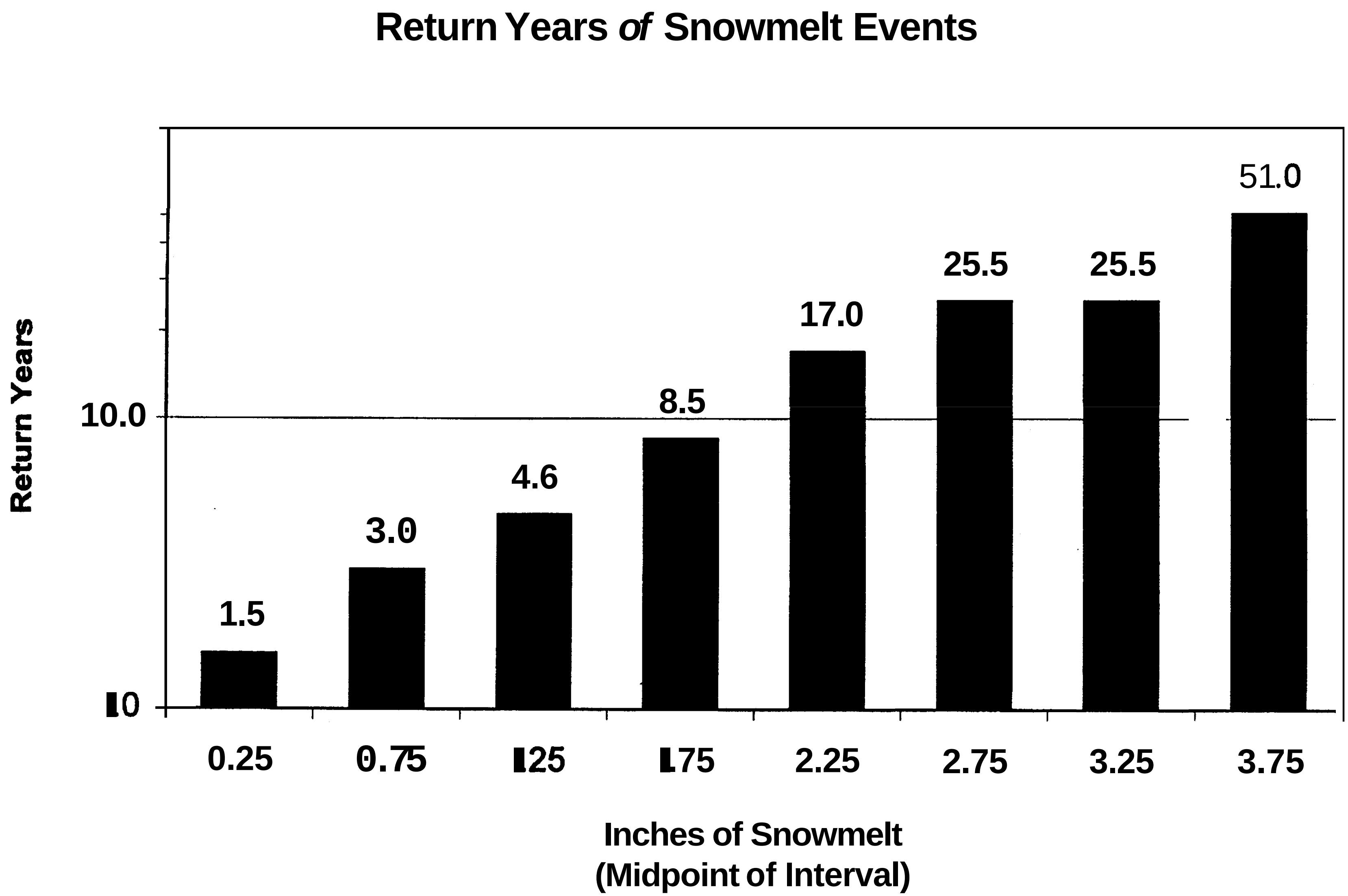

Figure 7. Snowmelt Return Events 1950–1999.

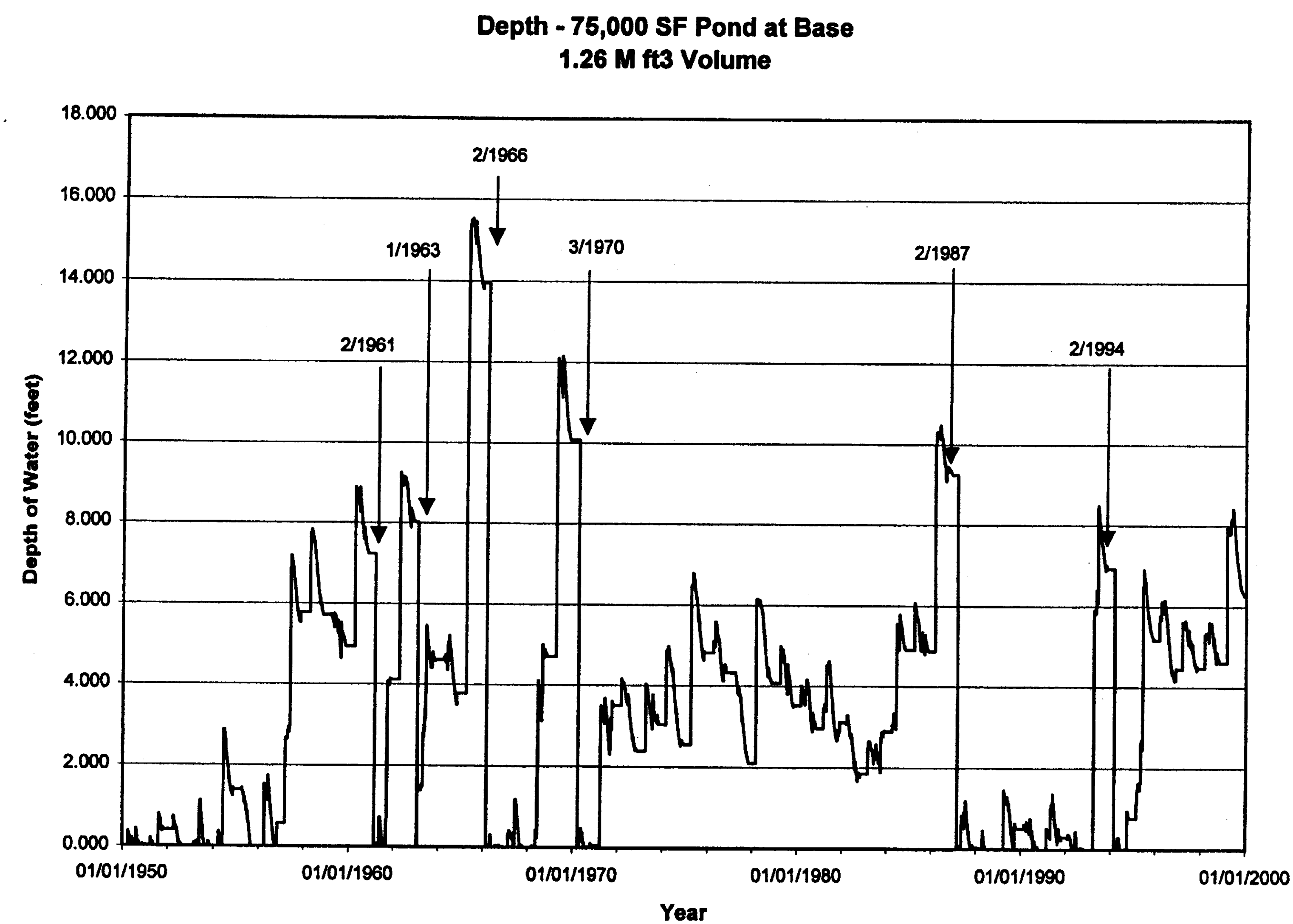

Figure 8. Depth of Water in P 1950–1999.

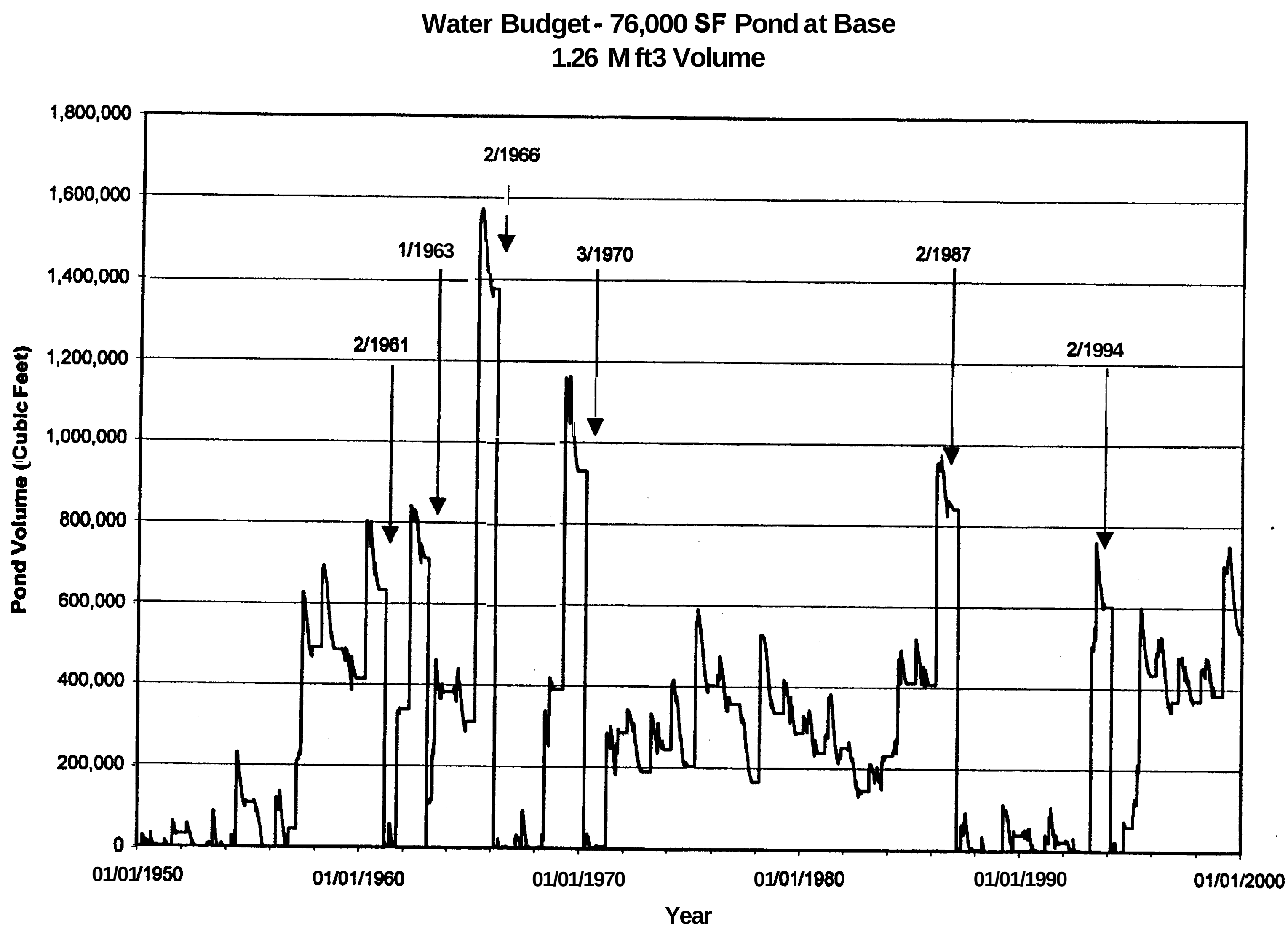

Figure 9. Cumulative Volume of Water in the Pond 1950–1999.